AD 480157

Foreword

The present report, which is preliminary in nature, is based on a "first look" at some of the human factor aspects of the combined Army aircraft operator—clothing—equipment—aircraft system. Only a few of the multitude of interrelated problems could be examined in this study. A more exhaustive attack is required to provide an adequate definition of all the problems of the system.

The present study was a cooperative venture with personnel participation by the Transportation Corps, US Army Aviation Board CONARC, and the Quartermaster Corps (who assumed primary responsibility for the coordination and conduct of the study). The other Technical Services were contacted and some expressed interest but were unable to assign personnel to the team.

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Introduction

1.1 Of all the tasks man has learned to perform, that of flying an aircraft probably comes the closest to demanding the limit of his performance capabilities. Because of this, careful consideration must be given to any change in the performance requirements of an aviator. The aviator's job requires that he spend long periods of time monitoring the performance of his aircraft. In addition, at certain times he must receive, interpret, and act on information rapidly and in ways demanding maximum use of his capabilities. If these primary task requirements are coupled with the stresses of combat it becomes evident that anything added to this system of operator, aircraft, and military environment must demonstrably facilitate overall performance of the system.

1.2 In order to make decisions on the advisability of providing additional items of equipment for the Army aviator, it was necessary to obtain as much information as possible regarding problems involved. It is the purpose of this study to identify the human engineering problems associated with the design of personal equipage in terms of safety, compatibility between the equipped pilot and the equipment he must operate, and his operating environment.

1.3 As a group, the number of Army aviators has increased greatly in proportion to the rest of the Army, and it appears that this growth will continue in the future. Concepts of future warfare emphasize the need for mobility in Army operations, particularly within the theater of operations. It is a good estimate that a considerable amount of this mobility can be obtained by the use of Army fixed and rotary wing aircraft. At the present time there is about one Army aviator per one hundred and eighty persons in the Army. As Army aircraft become a more common mode of troop transportation it can be anticipated that this ratio will increase.

1.4 The reports from Army aviators, particularly those during the Korean conflict, were that the items of personal equipage normally used by Army aviators in routine flying were not adequate for use during combat missions. Furthermore, as information concerning the hazards in the aviator's environment was compiled, it became evident that existing items were not adequate even for routine flying. From this information it was determined that the Army aviator needs additional protection from two hazards in his environment; one, hazards during a crash, particularly to the head, and two, hazards of personal injury due to enemy fire. This investigation was undertaken primarily to study these two hazards and with intent to consider others that may arise.

Methods

2.1 The following sources of information were used in conducting this investigation:

1. Interested staff agencies in the Department of the Army were visited.

2. Contract agencies working on problems of flight safety and crash protection were visited.

3. Orientation flights were made by research personnel in standard operational fixed and rotary wing aircraft of the U.S. Army.

4. Research team personnel attended briefings on present and future concepts of employment of Army aircraft.

5. Pilots with combat experiences were interviewed.

6. Pertinent technical reports were reviewed.

7. Other services and United Kingdom agencies were contacted (6).

2.2 The persons who composed the team which conducted this study are assigned to the Quartermaster Research and Engineering Command, the Transportation Research and Engineering Command, and the U.S. Army Aviation Board, CONARC. The project was undertaken as a joint effort. The skills that were represented on this team are: extensive experience in military and civilian aviation, chemical engineering and plastic headgear design, applied psychology, and clothing design.

Subjects

3.1 Subjects for the interview section of this study were 43 Army aviators who were interviewed about their combat experiences. All were rated Army aviators with combat flying experience in World War II and/or in the Korean conflict. The great majority had their combat experience in the Korean conflict. Some pilots who had survived recent crashes with Army aircraft were also interviewed.

3.2 The sampling was opportunistic since sufficient data about the past and present aviator population was not available to provide any basis for a better sampling plan. In fact any representative sampling plan would still be subject to the criticism of bias since critical data is not available from those who were killed in action. The sample consisted of many of those combat experienced Army aviators present for duty at Fort Benning, Georgia, and Fort Rucker, Alabama, during September 1957.

Procedures

4.1 The procedures used to obtain interview data from the Army aviators are described below. When he reported for the interview, each aviator had explained to him the nature of the subject matter for discussion. He was informed that the team was investigating factors which should be considered in the design of crash helmet and armor protection. He was assured that what he said during the interview would be held in confidence and reported anonymously. During the initial phases of the investigation the subjects' responses to interview questions were recorded on a tape recorder; later written records were maintained. Subjects were asked a number of questions to identify when and where they had experienced combat flying. They were then asked a series of questions intended to provoke remarks about their combat experiences and other subjects that they felt were germane to the topics of interest. Questions were asked by team members as a group. The appendix includes a summary of the questions asked.

Results

5.1 Each combat operation has its own history and serious bias could result from sampling only certain phases of it. In order to determine how representative the sample was of the population from which it was obtained the following analysis was performed. The period of hostilities during the Korean conflict was divided into quarters and a tally given to each quarter in which each of the aviators interviewed reported he had combat experience. The results of this analysis are presented in Table I.

TABLE I

THE NUMBER OF INTERVIEW RESPONDENTS WHO WERE FLYIN DURING EACH QUARTER OF THE KOREAN CONFLICT BASED ON 36 AVIATORS

Quarter of Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Calendar Year				
1950		1*	12	13
1951	14	15	15	6
1952	4	5	10	9
1953	10	10	8**	

* First Quarter of Hostilities
**Last Quarter of Hostilities

5.2 It is to be noted in Table I that the sample did not contain an equal number of pilots present and flying in combat during each quarter of the Korean action. The mean number of respondents per quarter (exclusive of the first quarter of the action) is 9.3. There is maximum representation in the sample from those phases of the conflict occurring during the summer and fall of 1950 and the winter, spring, and summer of 1951 and minimum representation from the late fall of 1951 and the winter and spring of 1952.

5.3 Of the 43 aviators reporting combat hours, 16 reported combat experience during World War II. This experience was scattered as to theater and type and dates of assignment. Two aviators could not remember the number of combat hours. Thirty-six aviators reported flying in combat in Korea, and only one could not recall the number of combat hours he had flown. In total, the interview data represents a reported 17,610 combat hours with 4,880 hours in World War II and 12,730 hours in Korea. The average (arithmetic mean) for World War II is 349 hours, and that for Korea is 364 hours per man. The overall mean is 359 hours per man per conflict. All distributions are positively skewed with medians close to 300 hours. The greatest number of hours reported for any individual in any given conflict was 900 hours; the least ten hours.

5.4 Another aspect of overall sampling is the sample of aircraft that is covered in the data. The number of pilots reporting combat experience in each of the seven Army aircraft is presented in Table II.

TABLE II

THE NUMBER OF PILOTS IN A SELECTED SAMPLE OF 43 PILOTS REPORTING COMBAT EXPERIENCE IN EACH OF SEVEN ARMY AIRCRAFT

Aircraft	Number of Pilots Reporting
L - 4	15
L - 5	19
L - 16	11
L - 17	10
L - 19	33
L - 20	5
H - 13	7

Armor Protection: An analysis of the questions asked (see appendix) pertaining to protection from enemy fires is presented in Table II and Figures 1, 2, and 3. In interpreting this data it must be remembered that the previously mentioned biases and in addition those biases due to the selectivity of respondent's memory are present.

TABLE III

THE TYPES OF FIRES ENCOUNTERED AND HITS RECEIVED AS REPORTED BY 43 ARMY AVIATORS*

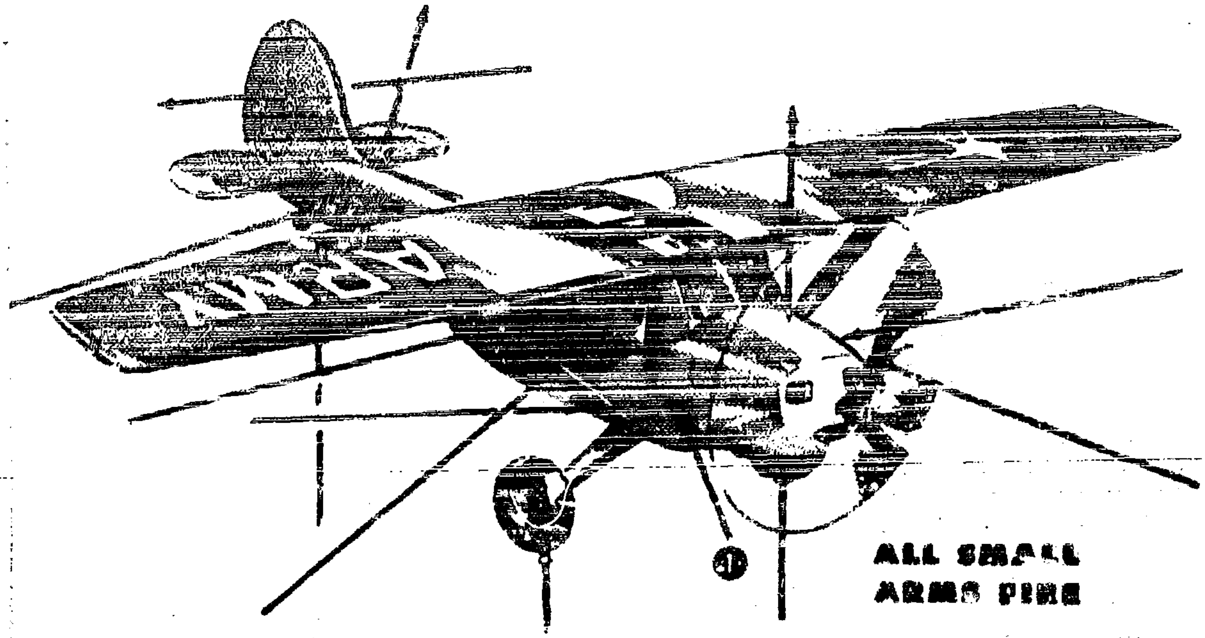
Types of Fires	Fires Encountered	Hits Received
Small Arms**	86%	65%
Fragmentation***	77%	26%

* Includes only those hits which were recalled by aviators interviewed.
** Includes single round hits up to and including 51 caliber.
***Includes all larger rounds capable of fragmenting or fragments thereof.
Percents reported are of pilots reporting fire encountered or hit received compared to all interviewed.

5.6 Fires encountered were defined as those fires which the aviator reported as being directed at his aircraft. Hits received are defined as those which left evidence on his aircraft. Small arms are to include single missile rounds up to and including 51 caliber. Fragmentation includes rounds of larger caliber and fragments from various rounds including both anti-aircraft and artillery or mortar.

5.7 Figures 1, 2, and 3 depict the location and, to some extent, the damage received by the aircraft. Only those hits about which the aviator could recall enough information to make an accurate plot are recorded. Therefore, here again the selectivity of human memory is operating. Although the aircraft depicted is of the L-19 type in a normal flight attitude the actual hits were received on all of the previously mentioned fixed wing aircraft types and the aircraft were frequently in a climb, bank or dive attitude when hit. Figure 1 depicts hits received at altitudes below one thousand feet above the terrain. Again small arms are defined as up to and including 51 caliber rounds. It is interesting that all of the hits reported for this altitude range including those upon which information was too incomplete to permit plotting were small arm hits. Figure 2 depicts those hits reported between 1,000 and 5,000 feet. Here there is a mixture of the types of fire received and the angle of penetration of direct fire is, as to be expected, more nearly vertical. Figure 3 depicts hits at altitudes over 5,000 feet above the terrain. All of the hits depicted and reported at these altitudes are of the larger caliber anti-aircraft variety. This is quite reasonable as this is a long distance for a rifle and beyond the tracer burnout for larger machine guns.

5.8 Thus there seems to be a relationship between altitude and type of hit received. However this relationship may not be a simple one. The character of any armed conflict changes as it develops. To investigate if such



ALTITUDE UNDER 1000 feet

FIGURE 1

Figure 1 is a composite of the hits which were reported at altitudes below 1000 feet. The figure illustrates only those hits about which respondents could recall enough information to permit accurate plotting. 1 A 9 mm rifle projectile entered here, came through the pilot's right hip and came out his left shoulder. The right leg was paralyzed.

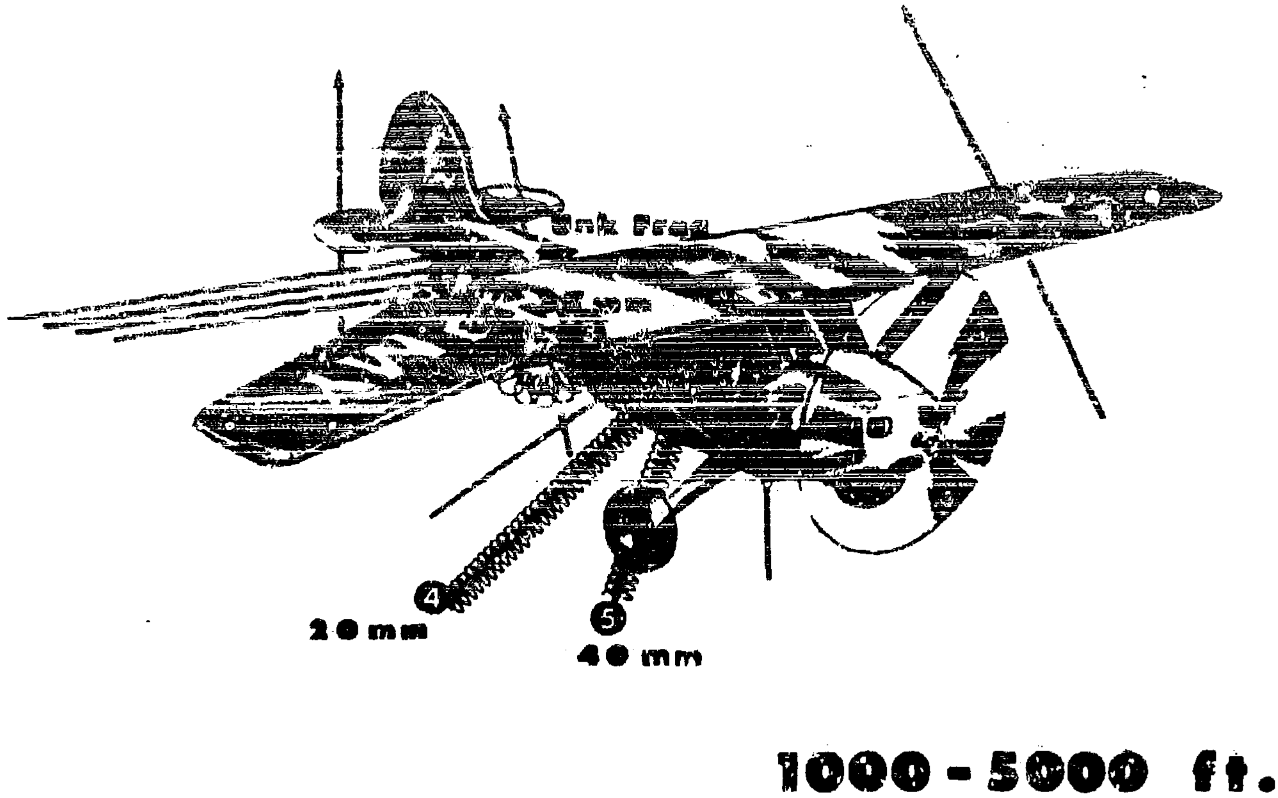
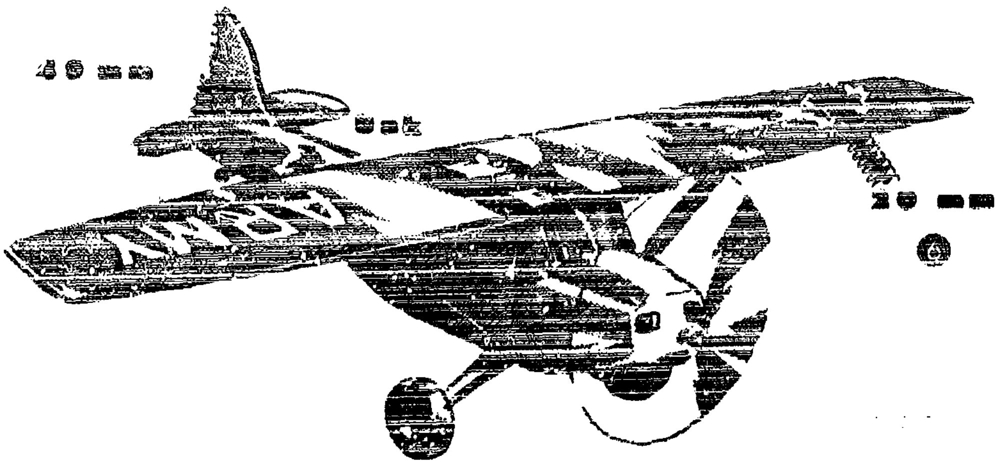


FIGURE 2

Figure 2 is a composite of the hits which were reported between the altitudes of 1000 and 5000 feet. The figure illustrates only those hits about which respondents could recall enough information to permit accurate plotting.

A fragment from this hit injured the right forearm of the pilot. ③ This hit took off the right wing. The pilot and observer were both hit, the pilot on the right side of the head, the observer in the face and head. Both occupants had to parachute to safety. ④ This hit caused the pilot to receive small fragments in his hand and heel, the observer received about 40 small pieces in his lower back. ⑤ This hit caused the pilot to be wounded in the left leg, he lost consciousness and the observer flew the return mission.



Over 5000 ft.

FIGURE 3

Figure 3 is a composite of the hits which were reported at altitudes above 5000 feet. The figure illustrates only those hits about which respondents could recall enough information to permit accurate plotting. ⑥ From this the observer was killed and the pilot wounded in the head and arm. The pilot was forced to parachute to safety.

changes may have affected the relationship between altitude and hits a first versus last half of conflict type of analysis was performed on the hit and altitude data. Those hits reported by pilots serving during the first five quarters of the Korean conflict are compared to hits reported by pilots serving during the last five quarters of that conflict. This data is presented in Figure 4.

5.9 The difference in altitudes at which pilots reported hits during the early and later periods of the Korean conflict is presented in Figure 4. During the later period of the conflict hits occurred at higher altitudes. The differences were evaluated statistically with the Mann-Whitney U Test. The differences were significant beyond the .05 level. However, the fact that no fragmentation hits were reported during the first period can easily make this open for misinterpretation. It is generally conceded that anti-aircraft weapons became more readily available to the enemy for employment in forward areas as the Korean conflict progressed. Therefore, it is a matter of question as to what are causes and what are effects in this three way relationship of time, altitude and type of hit received. However, that there was a relationship between altitude, regardless of the aviator's reasons for changing it and the type of hit received is quite apparent from Figure 4. This information can be used in evaluating the aviator's reasons for selecting a particular altitude during a combat mission and therefore be of help in determining the type and extent of the hazard for which protection may be designed.

5.10 Another type of information that is useful in determining combat hazards is what types of field expedients have been used by Army aviators to protect themselves in past combat operations. Consideration of these factors may tend to increase the acceptability of an end item by giving more assurance to the user that it is accomplishing or will accomplish its function. Of the 43 pilots who were interviewed, 26 gave affirmative answers when asked if they had ever used any type of field expedient as protection from enemy fires (see appendix). All of the expedients mentioned were intended to give protection to the seat area. Three of the expedients mentioned covered floor area in addition to the seat. Fourteen indicated they had used materials from flak suits or armored vests and 12 had used other materials, ranging from pieces of armor plate and stove lids to sponge rubber. Following the [illegible] line of questioning nine aviators made comments generally favorable to [illegible] protective vest and eight made comments generally unfavorable to the use of a protective vest. Eight aviators made comments relevant to the armoring of the individual or the aircraft, four advocated armoring the aircraft, two thought the armor should be on the man and two believed there was no requirement to armor either the man or the aircraft. In all cases the aviators expressed a concern over the weight of the proposed protection and the effect of this weight on the aircraft performance.

5.11 Finally, hits to either themselves or passengers were reported to have occurred to nine persons. The location of these hits are presented in Table IV. This table suffers from the unavailability of data from aviators killed in

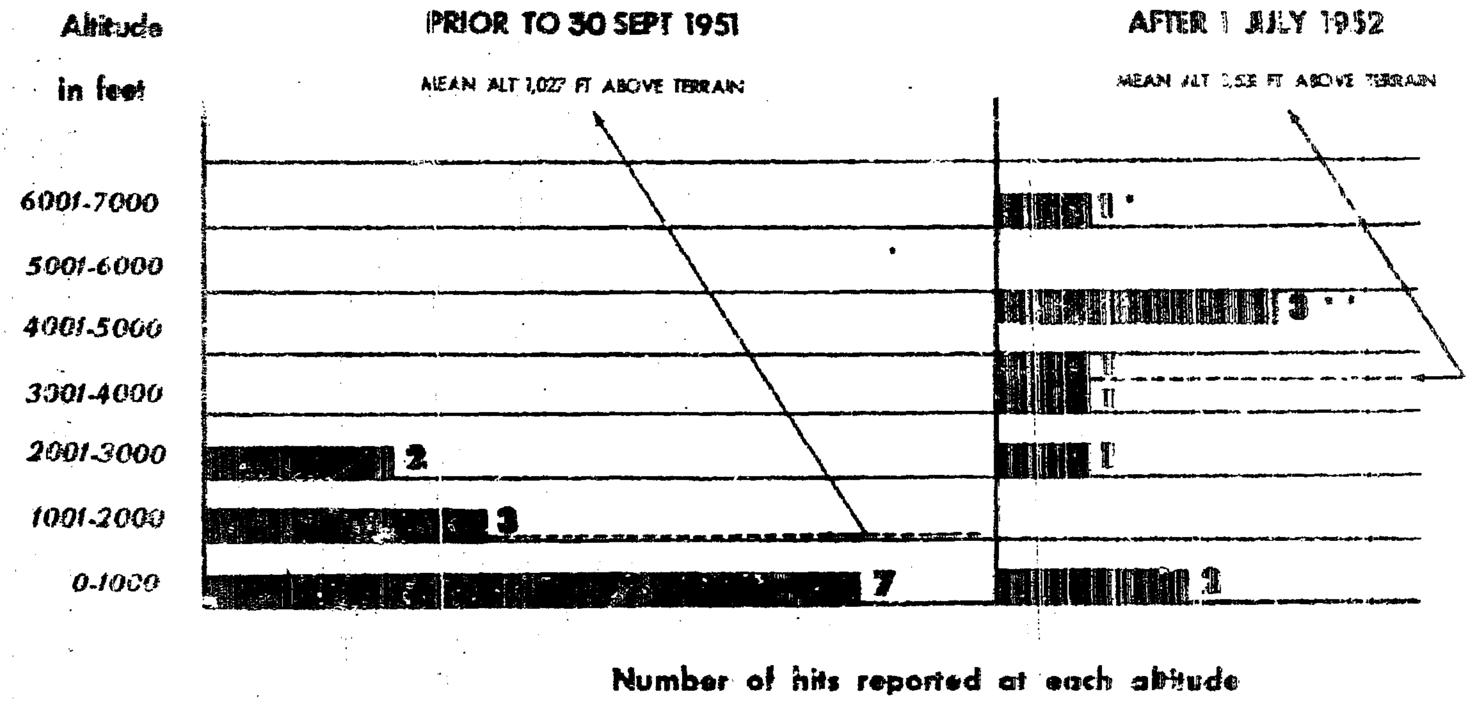


FIGURE 4

The number of Army aviators reporting hits at various flight altitudes during two periods of the Korean conflict.

SMALL ARM HITS
FRAGMENTATION HITS
THE MEANS WERE CALCULATED FROM THE RAW DATA

action. The death reported was of an observer riding with one of the pilots interviewed. Four of the nine persons were wounded by small arms and five by fragments.

TABLE IV

THE GENERAL LOCATION OF INJURY TO NINE PERSONS WOUNDED IN ARMY AIRCRAFT

Area of Entry	Small Arms	Fragments
Head	1	3
Upper Extremity	1	4
Thoracic Front	1	
Buttocks	2	1
Lower Extremity	3	3
Death		1

5.12 Crash Protection: Another area that was investigated as a source of hazard to the Army aviator was the crash environment. The scope of this investigation was limited to head protection. However it must be kept in mind that any protection offered by a crash helmet type of equipment constitutes only a part of what has been termed "crash worthiness".

5.13 Preliminary talks highlighted the head as a particularly vulnerable part of the anatomy during an aircraft crash and during the interviews the subject was pursued further. Aviators were asked to state a preference for crash or ballistic protection by answering a hypothetical question. The question was; "If it were possible to make a helmet that only protected you from enemy fires or one that only protected from the hazards of a crash, which would you prefer?" Eighty-five percent answered they would prefer crash to ballistic protection, 11 percent answered they preferred ballistic to crash protection and four percent insisted that they felt that there was no need for a helmet for the Army aviator.

5.14 The number of pilots interviewed who had crash experience was rather small, consisting of only four aviators, as the study group was primarily interested in getting combat information. No pattern of injury could be established from these four reports. However, when larger numbers of accidents are analysed a pattern of injury does emerge.

5.15 The sources of information furnishing data on larger samples of aircraft accidents are both secondary sources. One is the U.S. Army Board for Aviation Accident Research (1), the other is the Aviation Crash Injury Research of Cornell University (3).

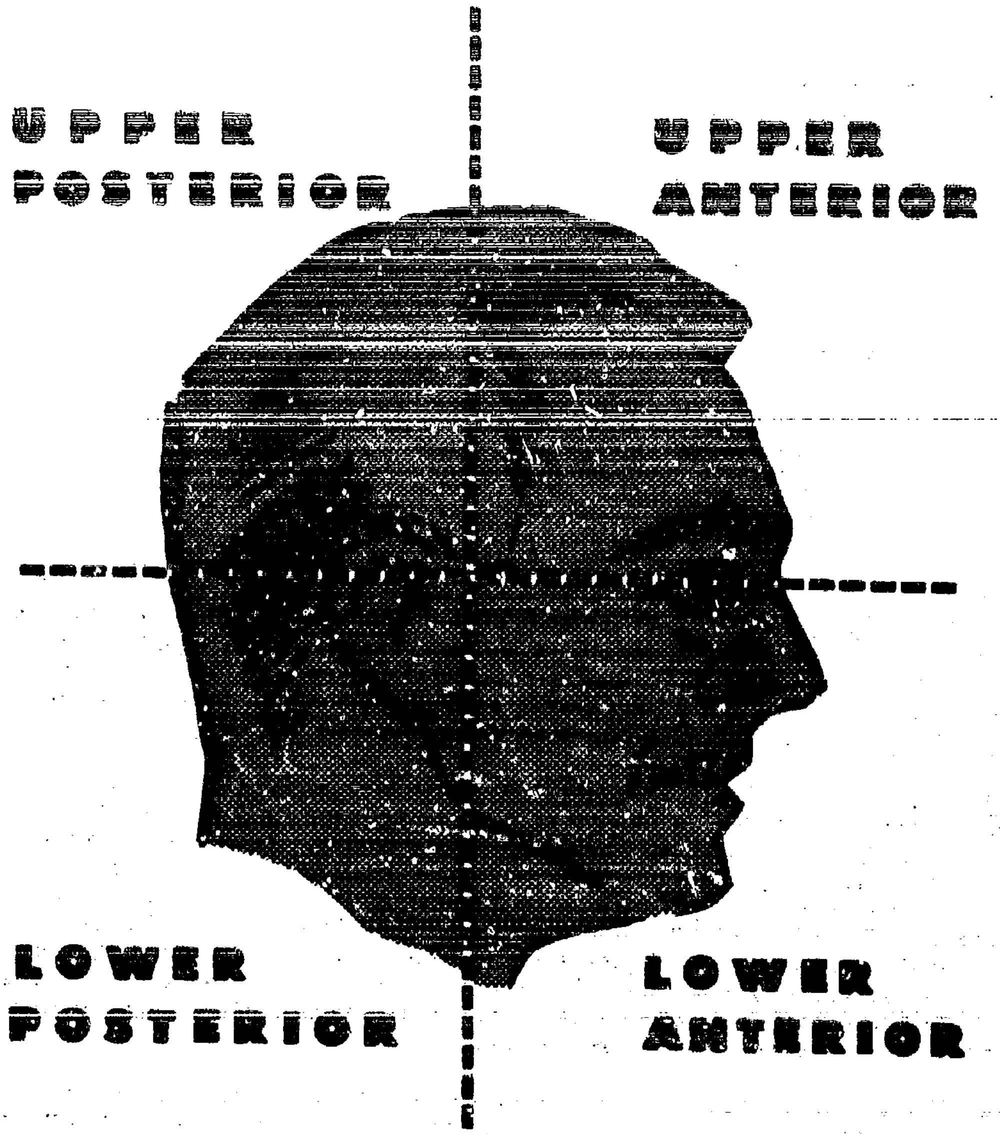


FIGURE 5

The division of the head which was used in the site of injury analysis reported in Table V.

TABLE V

THE PERCENT OF A SAMPLE OF 139 SURVIVORS OF LIGHT PLANE CRASHES WHO SUSTAINED HEAD INJURIES

Site of Injury	Observed Percent	95% Confidence Limits Lower	Upper
Upper Posterior	4	1	10
Upper Anterior	45	32	57
Lower Posterior	10	5	21
Lower Anterior	42	28	53
Type of Injury			
Fracture	18	8	27
Concussion	37	25	49
Broken Neck	5	2	13

A report of the Cornell Aviation Crash Injury Research contains the information, that of 800 survivors of crashes in light aircraft, with each survivor injured to some extent and with each having worn a safety belt, 88 percent sustained injuries to the head. The head is reported as the most injured body area. The report also states that..."dangerous head injuries are sustained by nearly eighteen percent of survivors"...This information evoked enough interest so that the team made a separate analysis of the records of the Crash Injury Research in an effort to locate the site of the injury to the head. An analysis of this data is presented in Table V. The four sites on the head were determined arbitrarily by dividing the head as illustrated in Figure 5.

5.16 A summary of head injuries of Army personnel involved in crashes of Army aircraft during the first two quarters of calender 1957 were analysed in the same manner as the Crash Injury Research Data. Where sufficient data was available to permit plotting, the proportions computed for site of injury fell within the confidence limits given in Table V. The records of the U.S. Army Board for Aviation Accident Research reveal that during the first two quarters of 1957, 69 persons were injured in Army aircraft, 43 receiving injuries to the head. During the same period there were 26 fatalities, of these fatalities 18 sustained head injuries. Autopsy reports indicated that two died of head injuries alone and indicated that in three other fatalities the cause of death may have been due to a head injury. During this period 100 percent of the rotary wing occupants who had shoulder harness available to them were wearing them when they crashed. Seventy-eight percent of the fixed wing pilots who had shoulder harness available were wearing their harness when they crashed. Reports indicate that shoulder harness are not installed in all aircraft. In order to give a more general picture of the situation over a longer time period a summary of Army crash data for 1956 and the first half of 1957 is presented in Table VI.

TABLE VI

U.S. ARMY FIXED AND ROTARY WING AIRCRAFT ACCIDENT DATA FOR 1956 AND PART OF 1957

Year	Number of Accidents	Number of Injuries	Number of Head Injuries	Number of Fatal Head Injuries
		Fixed Wing		
1956	12	17	16	8
1957*	12	27	19	8
Sub Total	24	44	35	16
		Rotary Wing		
1956	17	26	16	5
1957*	6	10	5	3
Sub Total	23	36	21	8
Grand Total	47	80	56	24**

* Through 21 June, 1957

** 13 occurred in non-survivable crashes and 11 in crashes which were survivable if suitable headgear had been worn (as reported by the U.S. Army Board for Aviation Accident Research)

5.17 Although a need for head protection as such may be established, protection is still a general crash worthiness problem calling for optimum balance between the characteristics of the aircraft and the protection provided the man.

5.18 Noise Hazards: The problems of noise in a military environment are wide-spread and promise to become even more complicated in the future as the equipment that soldiers must operate becomes more powerful. In this respect the Army aviator is not an exception although there are certain unique characteristics in his acoustical environment. Rotary wing aircraft probably present the greater problem as far as ambient noise level is concerned. Table VIII illustrates the overall sound level in several Army helicopters as obtained from several secondary sources (2, 7).

5.19 As the data were not all collected by the same organizations there is no guarantee that the same methods were used, therefore the data should not be used as a comparison between aircraft but only to illustrate the high overall noise level in all the aircraft studied. It is also of interest that band analysis of the noise of these aircraft places the peaks in sound pressure level at frequencies below 1000 cycles per second. This is the

low end of the frequency spectrum where current attenuation practices are the least effective. The noise levels reported exceed the accepted industrial damage risk criteria which were developed for exposure for eight hours a day.

TABLE VII

OVERALL LEVEL OF SOUND PRESSURE IN DECIBELS,* IN THE CABINS OF CERTAIN ARMY HELICOPTERS WHILE HOVERING

Aircraft Designation	Sound Pressure in Decibels
H - 13	118
H - 19	120
H - 21	108
H - 25	110
H - 34	118

*RE 0.002 Dynes/cm^2

5.20 The fact that temporary hearing losses can result from noise levels encountered in Army helicopters is indicated by the work of the Surgeon of the U.S. Army Aviation School (5). In his study, which investigated noise in the H-37 aircraft and various methods of attenuation, the subjective method was used. These investigations indicate that an exposure of approximately three hours in the cargo deck of an H-37 helicopter with unprotected ears can result in generalized auditory fatigue with a moderated decibel loss. The investigation indicates that a "well fitted" crash helmet does much to reduce this loss. However there is some indication that this is not an all or nothing type of problem. That is, it may not be desirable to just impose all available attenuation around the aviator's ears. All of the pilots who were asked if they felt that they used aircraft sounds in flying indicated that they did so. They indicated that elimination of all aircraft noises would be undesirable. They also indicated that there were times when the aviator wanted to hear more of what goes on about him and other times when he would want to hear less.

Discussion

Ballistic Protection

6.0 The team was not able to secure information with which to compute a reliable estimate of the exposure of Army aviators to enemy fires and an estimate of the effects of this fire for any particular conflict. This means that quantified information on the extent of the hazard faced by Army aviators during combat which may be balanced against the cost in weight of passive protective devices against enemy fires cannot be presented. Therefore

any discussion of protective devices or armor features discussed is contingent upon a need for protecting the aviator from enemy fires being established upon criteria other than the information contained in this report.

6.1 The results in the ballistic protection section indicate that a relationship exists between altitude and type of hit received. This information may be of considerable use in assessing the relative dangers of fires if one considers the factors influencing an aviator's selection of altitude. Confining the discussion to the selection of altitude on a combat mission, the factors involved are:

1. Performance characteristics of the aircraft,
2. Prevailing weather conditions,
3. Terrain,
4. Nature of the mission,
5. Weapons available to the enemy.

6.2 The first factor is fairly constant although it is affected to some degree by the second and third factors. Every aircraft has limitations in terms of its rate of climb, speed, and ceiling which are very germane to a pilot's altitude selection. These considerations are affected by weather in that air density affects the performance of the aircraft. Also the terrain affects altitude selection in conjunction with aircraft performance in that the aviator wishes to be able to clear obstacles with a margin of safety within the performance capabilities of his aircraft. Weather influences this decision in that visibility of the terrain will guide him in how much of a safety factor he will demand to clear obstacles. The nature of the mission, usually results in preferences for certain altitudes. For example, many of the missions assigned to Army aviators have a surveillance type requirement. This means that in order to accomplish his mission the aviator must select an altitude that is low enough to distinguish ground detail and high enough to see a large enough area at one time. Weather and terrain influence this decision in that both influence visibility.

6.3 Last but not least, the weapons available to the enemy influence this altitude selection. The pilot will attempt to combine all other factors and also try to find an altitude which will allow him to accomplish his mission where the enemies' weapons are least effective.

6.4 Of these five factors it is assumed that during both the early and late periods of the Korean conflict the first four, performance of the aircraft, prevailing weather, terrain, and the nature of the mission, varied more or less in a random way within the same limits of possibilities. Therefore it is assumed that these factors did not systematically affect altitude

selection between the two periods. In assessing the role of the fifth factor, the weapons available to the enemy, the following considerations are relevant.

1. During the Korean conflict, heavier anti-aircraft weapons became more available to the enemy for employment in forward areas during the latter period of the conflict.

2. Small arms fire are more effective at lower altitudes and heavier anti-aircraft fires are more effective against aircraft at higher altitudes.

3. The average hit altitudes for the second half of the Korean conflict is higher than in the earlier half.

6.5 Keeping these factors in mind the question is asked, why did aviators increase their mission altitudes when the enemy had available more heavy anti-aircraft weapons? Would it not seem logical that they were selecting an altitude at which the enemies weapons were more effective? Or might it be that as aviators became more aware of the losses incurred through small arms fires at lower altitudes, that as the enemy increased his small arms fires as he realized that these low flying aircraft were vulnerable to small arms fires, that the aviators chose to take their chances at higher altitudes with the heavier caliber weapons. In the future, the trend towards increased use of electronic surveillance and electronic guidance and fire control will probably reverse these odds for the aviator and force him to select altitudes which are quite low in order to get in the altitude range where electronic systems lose reliability. It is concluded that this lower altitude range will still be an area where small arm fires will present a considerable hazard to the Army aviator.

6.6 What effect does this have on the type of protective equipment the aviator will need? The major difference between small arms fires and fragmenting rounds, as far as the protective requirements are concerned, are the relative energies involved. The small arms have more kinetic energy as they are generally of greater mass and usually have a velocity on impact equal to or greater than fragments. To provide effective protection against small arms an armor of greater weight than the light weight exclusively textile armor is required. For example armor to defeat 30 caliber ball ammunition at operational ranges is approximately seven times heavier than the textile armor used against fragments only. Armor for protection against small arms probably would best be a combination of textile materials and/or materials having greater rigidity. Because of the nature of these materials, i.e. their rigidity and weight, it would not be feasible to place the material on the aviator's body. To do so would interfere with the movements of the operator to quite a large extent.

6.7 Taking these factors under consideration and also considering the weight restrictions, the pattern of fires received and body damage resulting it is felt that ballistic protection capable of protecting from small arms fires

for the bottom, back, and to some extent the sides of the body should be an integral part of the protection system in all aircraft which may be flown in combat.

Crash Protection

6.8 The results indicate that there is a real need to give greater protection to the aviator's head. It is believed that there are two ways in which the findings of this report can help in this area. In the first place an analysis of site of injury data indicates the face to be the most frequently injured area. From inspection existing helmets do not seem to provide adequate protection from impacting objects in facial areas. Although the lower face may sustain relatively greater damage than the rest of the head without fatal results, such damage does result in a loss of consciousness during and shortly after a crash and may prevent occupants from taking timely action which would prevent a rather minor crash from becoming a more serious one, e.g., evacuation after water ditchings, evacuation before a fire occurs, etc. Therefore it is concluded that more protection is necessary for the facial area.

6.9 A second application of the results of this study of head injury would be to attempt to reduce the extent of brain damage. When the human head is decelerated in an aircraft crash two things may happen. First the skull can be injured from the outside by impacting against objects. Much research has been done and is continuing to be done in this area (4). Secondly, the human head should not be considered as a solid object, but rather a fairly solid case with a very sensitive organ floating in it. Therefore when the head is decelerated over a short period of time serious damage can occur inside the skull while the outside remains completely intact. It is suggested therefore that research on the effects of deceleration and brain damage be investigated to see if it is feasible to reduce this deceleration during crashes to limits where damage will not occur. Such information will furnish guidance for decisions on whether such deceleration reduction is possible through helmet design, the design of areas in the aircraft likely to be struck by the head, and head motion controlling devices.

Noise Hazards

6.10 The results on noise hazards indicate that the aviator who flies rotary wing aircraft certainly needs some protection from the acoustical environment. However, it is felt that placing all the available attenuation into an Army aviator's helmet may not be the solution to the problem. The fact that all of the aviators asked indicated that they used some auditory reference to fly makes such an approach questionable for the following reason. Even though the present state of technology would not permit a complete dampening of sound at the aviator's ear, a helmet with attenuation characteristics that would give maximum available protection in the noisiest of Army aircraft, may reduce listened to sounds in a less noisy aircraft to a point that would make the aviator's task more difficult and hazardous. It is felt that an answer to

this problem could be found by one of three approaches. One approach is an analysis to determine if there are critical frequencies which pilots use and what their levels are in different aircraft. The attenuation characteristics could then be balanced against these requirements. However, such research would be quite costly and time consuming. A second approach would be to provide a method of adjustment of the amount of attenuation, or a by-pass of attenuation, which the aviator may use to suit his requirements. This adjustment would also make it easier for him to perform his ground role without removing his helmet. A third approach would be to provide all possible attenuation and see if it affects the flying performance of aviators flying all available types of aircraft.

General Problems

6.11 The aviators who were interviewed were not restricted in the comments that they could make. For instance, many of the aviators were concerned about the weight of any proposed helmet. This is a problem that is recognized by developers here and in Great Britain. However the weight of an item is a difficult thing to quantify in an interview, so no specific development guidance can be given from the data obtained. There are two aspects to the weight problem. First there is the problem of total weight and secondly, the problem of how this total weight is distributed. It is felt that this problem can best be answered by experimental studies which would provide design engineers quantified data relating weight and weight distribution to the performance of the wearer. Thus they would have a quantified criterion against which to evaluate their designs.

6.12 In conjunction with helmet design most aviators also indicated that there was a need for some type of glare protection device such as a transparent eye shade which could be pulled down or pushed up. The aviators also felt that communication equipment should be integrated into the headgear.

6.13 Pilots were asked how they felt the head gear should be issued and almost all felt it should be issued on a personal issue basis. It should be noted that some pilots felt that crash helmet protection was not necessary. Upon further questioning it was determined that those aviators who felt that the helmets were not necessary also felt that the head was much less vulnerable to crash injury than the data would indicate. It is felt therefore that helmets for aviators should be introduced with some type of training program.

6.14 In addition to these comments others were made in more general areas. Seven of the aviators interviewed made statements indicating that present flying clothing is inadequate. They indicated that it was inadequate as to weight or protective characteristics and that the pocket placement was not adequate for accessibility when they are strapped into an aircraft seat. Cold weather requirements were mentioned as a particular problem. Two other items of equipment were mentioned that are worthy of particular note. One was aircraft seats which were criticized as not being comfortable enough and another was the insulated boot which was criticized as not having enough "feel" to be

an acceptable part of flying gear.

Recommendations

1. That the problems outlined in this report be considered in future helmet and body armor design.

2. That small arms ballistic protection be incorporated in any armor that may be developed for the Army aviator if the need for protection is established.

3. That the Army aircraft seat, restraining devices and aviator's clothing, including his parachute and survival kit, be investigated as a system to provide compatibility between the various items of equipment, best balance of armor protection for personnel and energy absorption during a crash.

4. That head protection for aviation crashes be developed and provided Army aviators, such protection to include a helmet designed for the Army aviator. That the helmet designed provide protection to the facial area to an extent that will reduce concussion.

5. That research be initiated to determine the effects of overall headgear weight and weight distribution on long term performance of tasks similar to flying.

6. That research be initiated on the effects of deceleration on brain damage and methods of absorbing impact energy.

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APPENDIX

INTERVIEW GUIDE FOR AVIATORS WITH COMBAT EXPERIENCE

1. Have you any experience flying Army aircraft in combat?

    a. WW II or Korea?
    b. What unit were you with?
    c. What period was this? (inclusive dates)
    d. How many combat hours did you fly?
    e. What types of aircraft did you operate?

2. Were you ever fired upon by the enemy?

    a. What types of fires did you receive?
    b. Was your aircraft ever hit? (if so, describe hits)
    c. Did you or any other occupant of your aircraft receive any hits? (if so, describe)
    d. What, generally, was your mission altitude?
    e. How high were you when you were hit? (true altitude above terrain)
    f. Were you ever knocked down completely, or did you ever have to make an emergency landing? Were you or any occupants of your plane injured as a result?
    g. Were you ever attacked by enemy aircraft? (if so, describe)

3. In your combat experience, have you ever utilized any field expedients as protection against enemy fire?

4. If it were possible to make a helmet that only protected you from enemy fires or one that only protected from the hazards of a crash, which would you prefer?

5. If all the sounds of your aircraft were removed, do you think you could still fly?

6. Have you ever worn the Army's armored vest in combat flights?

Other questions were asked which varied with the interviewee's experience.

APPENDIX

STATEMENTS OF ARMY AVIATOR [illegible]

1. Protective field expedients that used armored vests or armored vest materials:

We were issued flak vests, but sat on them rather than wore them; a round hit the vest and was stopped.

We put Air Corps flak suits on the floor, and also sat on them.

We used Air Corps flak suits under the seat pack parachute.

I used an old flak vest to sit on; I would not wear a flak suit.

I sat on a flak vest and hung one on the back of the seat.

I wore a Marine Corps type vest and put old ones on the bottom of the seat and on the seat back.

I used the Marine type vest, and sat on one.

We used to put the WW II flak vest on the floor and the seat, and also on the seat back.

I sat on a flak vest and a piece of scrap iron.

I wore a flak vest, and put old ones under the seat. The nylon vest and flak vest weren't too warm, and did not restrict movement.

We used to line the aircraft cockpit, one behind each seat. I wore a flak suit on several occasions. It restricts movement and created excessive fatigue.

I sat on the Army protective vest. (Marine Corps type)

I sat on an armored vest and had another one over the seat back. I also wore one. The vest was a little tight. I like the nylon one better than the plates, as it did not interfere with movement.

I used a flak vest cut up, under the seat and on the seat back.

2. Protective field expedients that used other materials:

I sat on armor plate.

I used an Air Corps flak seat out of a glider in Europe. ...armor plate was used on the seat...

I used a piece of [illegible] armor under the seat.

We used sponge rubber on the bottom of the aircraft and the seats. We didn't have any aircraft hit, so we didn't find out if it worked.

I used ¼" boiler plate on the seats for protection.

We used sand bags under the seat cushions in Korea.

I used a piece of the shield from a 105 Howitzer under my seat.

We used an armor plate on the seat.

I used a small piece of armor in the seat.

I put a plate under the seat; 3/8" steel.

3. Armor requirements:

With the present mission there is no requirement for body or aircraft armor.

The plane should be armored, and a vest worn, too.

Personnel armor might be wise, because it can be removed readily.

I would prefer body armor to armor on the aircraft.

I think you should armor the plane.

I would rather have armor in the aircraft than on the body.

I would rather have protection built in than on the person.

There is no requirement for body armor, but there should be light armor for the aircraft.

4. Comments favorable to wearing an armored vest:

We used flak suits in WW II.

I was wearing a Marine Corps type vest when I was hit and had to bail out.

I wore the Marine Corps type vest, and would wear it again.

I used a flak vest on, and old ones under the seat. The nylon vest and the flak vest weren't too warm, and did not restrict movement. (a duplicate)

I wore a flak vest in Korea and I would wear one again.

It takes less weight to armor personnel rather than the aircraft.

The flak vest worn in combat offered the pilot assurance, did not restrict movement or cause fatigue.

The man should be armored, it takes less weight if it's on the man, the vital portions of the aircraft should be protected.

I would wear a flak suit if it was available.

5. Comments unfavorable to wearing an armored vest.

I used an Army flak vest, it was too heavy.

The Air Corps flak vest is uncomfortable.

I occasionally wore a vest, it was hot and restricted movement, inconvenient.

I used an old flak vest to sit on. I would not wear a flak suit.

(duplicate)

I do not desire to wear body armor.

I don't want body armor.

A vest would increase fatigue.

.... I wore a flak suit on several occasions, it restricts movement and created excessive fatigue. (duplicate)

6. Statements about flying clothing.

Army aviators need a cold weather suit.

There is a definite need for a lightweight flying suit—too many zippers.

There is a requirement for temperate and arctic gloves.

There is a definite requirement for cold weather flying clothing.

Present winter flying suits are too heavy and too warm.

A lightweight flying suit is required.

I believe a requirement exists for both cold and warm weather flying gear for the Army aviator.

7. General problems mentioning specific items of equipment.

The thermal boot is unsatisfactory for flying.

We are using Navy helmets now and on long flights we take them off.

Most aircraft seats are uncomfortable.

Seats need to be more comfortable.

There is not enough feel in the insulated boot for flying.

I used the M-1 helmet for flying—unsatisfactory.

8. General problem areas.

A friend was shot down and crashed; there was a fire.

In designing helmets consider conversation between pilot and VIP's.

Require shoulder harness in all Army aircraft.

I would rather fly 10 fixed wing missions that 1 rotary wing mission in combat.

I feel that the cold is definitely a problem.